
अशक्त मिट्टी के लिए भूमि सुधार तकनीकों का
चुनाव — मार्गदर्शी सिद्धांत
(पहला पुनरीक्षण)

**Selection of Ground Improvement
Techniques for
Weak Soils — Guidelines**
(*First Revision*)

ICS 93.020

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.gov.in www.standardsbis.in

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Soil and Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

In poor and weak subsoils, the design of conventional foundation for structures and equipment may present problems with respect to both sizing of foundation as well as control of foundation settlements. A viable alternative in certain situations is to improve the subsoil to an extent such that the subsoil would develop an adequate bearing capacity and foundations constructed after subsoil/ground improvement would have resultant settlements within acceptance limits. This method/technique is called ground improvement which is used to improve *in-situ* soil characteristics by improving its engineering performance as per the project requirement by altering its natural state, instead of having to alter the design in response to the existing ground limitations. The improvement is in terms of increase in bearing capacity and shear strength, reducing settlement and enhancing drainage facility, mitigating liquefaction potential, etc of soil, as also improving lateral capacity in case of deep foundations.

This standard has been formulated to cover provisions with regard to necessary data to be collected to establish the need for ground improvement at a site, considerations for establishing need for ground improvement, selection of ground improvement techniques, equipment and accessories for ground improvement, control of ground improvement works and recording of data. The standard in Annex A presents various methods of ground improvement along with principles, applicability to various soil conditions, material requirements, equipment required, results likely to be achieved and limitations. This may be referred to for guidance for selecting the proper method for a situation.

This standard was first published in 1992. This revision of the standard has been taken up to incorporate modifications in light of latest developments in the field.

In this revision of the standard, the following major modifications have been incorporated:

- a) Considering that ground improvement may also be adopted for application other than construction of foundation, the title of the standard has been modified from 'Guidelines for selection of ground improvement techniques for foundations in weak soils' to 'Selection of ground improvement techniques for weak soils — Guidelines'.
- b) Some new terms and their definitions have been added and existing definitions have been modified;
- c) Provision on lime stabilization has been elaborated;
- d) Reference to IS 1893 (Part 1) : 2016 'Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*sixth revision*)' has been made for assessment of liquefaction potential of soil; and
- e) Provisions on methods of ground improvement have been modified.

For provisions relating to ground improvement by reinforcing the ground using stone columns so as to meet the twin objective of increasing the bearing capacity with simultaneous reduction of settlements, reference be made to IS 15284 (Part 1) : 2003 'Design and construction for ground improvement — Guidelines: Part 1 Stone columns'.

Whenever soft cohesive soil strata underlying a structure are unable to meet the basic requirements of safe bearing capacity and tolerable settlement, ground improvement is adopted to make it suitable for supporting the proposed structure. Both the design requirements that is shear strength and settlement under loading, can be fulfilled by consolidating the soil by applying a preload, if necessary, before the construction of the foundation. This consolidation of soil is normally accelerated with the use of vertical drains. For provisions relating to ground improvement by preconsolidation using vertical drains, reference be made to IS 15284 (Part 2) : 2004 'Design and construction for ground improvement — Guidelines: Part 2 Preconsolidation using vertical drains'.

Use of suitable geo-synthetics/geo-textiles may be made in an approved manner for ground improvement, where applicable as per this standard.

The composition of the Committee responsible for the formulation of this standard is given in Annex C.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding of numerical values revised (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

SELECTION OF GROUND IMPROVEMENT TECHNIQUES FOR WEAK SOILS — GUIDELINES

(*First Revision*)

1 SCOPE

This standard covers the guidelines for selection of ground improvement techniques using one or more methods.

2 REFERENCES

The following standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication the editions indicated are valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

<i>IS No.</i>	<i>Title</i>
1892 : 2021	Subsurface investigation for foundations — Code of practice (<i>second revision</i>)
1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (<i>sixth revision</i>)
6403 : 1981	Code of practice for determination of bearing capacity of shallow foundations (<i>first revision</i>)
8009 (Part 1) : 1976	Code of practice for calculation of settlements of foundations: Shallow foundations subjected to symmetrical static vertical loads
(Part 2) : 1980	Deep foundations subjected to symmetrical static vertical loading

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Ground Improvement — Enhancement of the in-place properties of the ground by controlled

application of techniques suited to the subsoil conditions.

NOTE — These techniques are used to improve the load bearing capacity and settlement potential of the loose or soft soil lying close to the surface or at depths.

3.2 Injection — Introduction of a chemical/cementitious material into a soil mass by application of pressure.

3.3 Liquefaction — It is a state primarily in saturated cohesionless soils wherein the effective shear strength is reduced to negligible value for all engineering purposes, when the pore pressure approaches the total confining pressure during earthquake shaking. In this condition, the soil tends to behave like a fluid mass.

3.3 Preloading — Application of loads to achieve improvement of soil properties prior to imposition of structural loads.

3.4 Soil Densification — A technique to densify cohesionless soils by imparting shocks or vibrations.

3.5 Soil Reinforcement — Rods, strips or geosynthetics (metallic or fabric) incorporated within soil-mass to impart resistance to tensile, shear and compressive forces.

4 NECESSARY DATA

4.1 The information as specified in **4.1.1** to **4.1.4** shall be collected to establish the need for ground improvement at a site, for selection of method to be adopted and for design of selected scheme.

4.1.1 Subsoil profile and soil characteristics down to a depth of about twice the width of the loaded area or up to dense/hard strata if encountered earlier shall be obtained. This information shall be acquired by conducting subsurface investigation as per IS 1892.

4.1.2 Engineering properties of subsoil shall include index properties, shear strength parameters, compressibility characteristics, etc.

4.1.3 Boreholes shall be supplemented by conducting a suitable number of static/dynamic cone penetration tests up to the depth to be improved. In conjunction with selected boreholes, these tests serve as an economical

and rapid method of establishing the state of subsoil before and after treatment.

4.1.4 Information shall be obtained with respect to nature of the proposed structure and area covered by it, intensity and nature of loading, permissible distortions which the structure can withstand.

5 CONSIDERATIONS FOR ESTABLISHING NEED FOR GROUND IMPROVEMENT

5.1 Based on subsoil data obtained from site and the loading exerted by the structure, foundation design shall be carried out from bearing capacity considerations and settlement analysis. Ground improvement is indicated if the net loading intensity of the foundation exceeds the allowable bearing pressure computed as per IS 6403.

5.2 Ground treatment may be required if even for relatively low loading intensities, the resultant settlement [computed in accordance with IS 8009 (Part 1) and IS 8009 (Part 2)] exceeds the acceptable limits for the structure both from view point of distortions induced in the structure and from operation angle. Specific cases may require different treatments according to the site conditions and project requirements.

5.3 Loose cohesionless deposits in seismic zones may be prone to liquefaction during earthquakes specially under high water table conditions. In such cases, analysis should be carried out for establishing liquefaction potential of the subsoil as per IS 1893 (Part 1). Ground improvement is called for, if such analysis establishes that the subsoil is prone to liquefaction.

5.4 Stability of soil in slopes can be enhanced by use of soil reinforcement.

6 METHODS OF GROUND IMPROVEMENT

6.1 Ground improvement is achieved by the methods covered in **6.1.1** to **6.1.5**.

6.1.1 Soil Densification

6.1.1.1 Soil densification is carried out by application of shock and vibration to the subsoil by appropriate technique and thereby causing rearrangement of the soil structure from a loose to medium to dense state. This technique is applicable to cohesionless soils.

6.1.1.2 Methods under this head include vibroflotation, vibrocompaction, compaction piles, blasting and dynamic compaction.

6.1.2 Pre-Consolidation

6.1.2.1 Expulsion of water from the pores causes consolidation of the soil thereby resulting in build-up of shear strength and substantially reduced values of final settlements of foundations. This is achieved by pre-compression of the subsoil by subjecting the area to a preload. Preload can be done by any suitable method and is carried out in stages to allow gradual build-up of soil strength enabling it to safely support further stages of preload. For poorly draining soils, such as soft clays, pre-compression is accelerated by installation of prefabricated vertical drains (PVD).

6.1.2.2 Preloading is applicable to fine grained soils such as silts and clays. Subsoils exhibiting high secondary consolidation characteristics may not be amenable to required degree of improvement by the preloading method.

6.1.2.3 Removal of water from pore spaces may also be achieved by application of an external electric field to subsoil, the process being known as electro osmosis.

6.1.3 Injection and Grouting

6.1.3.1 Injection of chemicals, lime, cement, etc, into subsoil improves subsoil by formation of bonds between soil particles. Mechanical stabilization of the soil can also be achieved by grouting under high pressure.

6.1.3.1.1 Lime stabilization is achieved by two ways depending upon the nature of the soil, thickness of strata, depth of strata, etc. Mixing of lime with clay is generally resorted to when the thickness of layer is small and clay is available at shallow depths. Lime column technique may be adopted at locations where soft clay extends to greater depths. The lime reacts with soil and increases its functional properties, thus decreasing the compressibility of soil.

6.1.4 Soil Reinforcement

6.1.4.1 Reinforcement introduced into the soil mass causes marked improvement in stiffness and consequently the load carrying capacity and stability of the soil mass.

6.1.4.2 Reinforcements may be in the form of dense granular materials in the form of stone columns. These are used where the primary requirement is to increase the vertical load carrying capacity.

6.1.4.3 Reinforcements may also be in the form of horizontal or vertical strips and membranes. These reinforcements serve significantly to increase the

capacity of soil to withstand tensile, shear and compression loads and contribute towards improvement of stability of soil mass. These include geotextiles, geomembranes, soil nails, ground anchors, strips, etc.

6.1.5 Miscellaneous Methods

6.1.5.1 Other methods used successfully include replacement of poor subsoil by competent fill. These methods, however have limitations of depths of application.

6.1.5.2 Improvement of properties of subsoils by heating and drying and by fusion at high temperatures have been employed with success. Soft soil has also temporarily been strengthened by freezing to improve its stiffness. These techniques have, however, limited application.

6.1.6 Choice of Method

6.1.6.1 Annex A presents a summary of various methods of ground improvement along with principles, applicability to various soil conditions, material requirements, equipment required, results likely to be achieved and limitations. This table may be referred to as guidance for selecting an appropriate method under a given situation.

6.1.6.2 Annex B gives applicable grain size ranges for different treatment methods.

6.1.6.3 For a particular situation, more than one method may appear to be suitable. In such cases, a relative study should be made for a proper selection. If necessary, a combination of more than one method may be adopted.

7 EQUIPMENT AND ACCESSORIES

The requirement of equipment and accessories will depend upon the method of ground improvement adopted. In practice, the type of equipment employed can vary considerably depending upon the substrata and project requirements. However, not only it is important that the equipment should be capable of

reaching the required depths but also the installation procedure should not adversely affect subsoil properties thereby reducing efficacy of treatment procedure adopted.

8 CONTROL OF GROUND IMPROVEMENT WORKS

8.1 Prior to commencement of ground improvement works, pilot boreholes with relevant field and laboratory tests shall be carried out in locations specific to area to be improved.

8.2 After completion of ground improvement work in a specific area, the field and laboratory tests shall be repeated to assess degree and adequacy of improvement of the subsoil.

NOTES

1 For medium and major works, it is desirable to initially earmark a trial area for establishing the pattern and efficiency of the treatment technique proposed to be employed and for optimization of the same.

2 It will also be beneficial to include a programme of instrumentation to monitor the behaviour of subsoil during loading by measurement of pore pressure, soil movements, earth pressures, foundation settlement, etc.

9 RECORDING OF DATA

9.1 A competent inspector shall be present to record the necessary information during execution of the ground improvement work.

9.2 Data to be recorded shall include:

- a) Sequence of operation of the work;
- b) Sequence and spacing of treatment points;
- c) Depth of treatment;
- d) Details of equipment employed and installation procedure followed;
- e) Records of instrumentation, if any;
- f) Results of soil tests before and after treatment; and
- g) Settlements during preloading.

ANNEX A

(Foreword and Clause 6.1.6.1)

GROUND IMPROVEMENT METHODS

	Summary of Ground Improvement Methods								
	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
<i>In-Situ Deep Compaction of Cohesionless Soils</i>	Blasting	Shock waves and vibrations cause liquefaction; displacement with settlement to higher density	Saturated, clean sands; partly saturated sands and silts (collapsible loess) after flooding	> 30 m	Explosives, backfill to plug drill holes, hole casings	Jetting or drilling machine	Can obtain relative densities of 70-80 percent; may get variable density; time dependant strength gain	Rapid, inexpensive, can treat any size areas; variable properties; no improvement near surface; Dangerous and requires expertise	Low
	Vibratory Probe	Densification by vibration; liquefaction induced settlement under overburden to produce a higher density	Saturated or dry clean sand	20 m (Ineffective above 3-4 m depth)	None	Vibratory pile driver and 750 mm dia open steel pipe	Can obtain relative densities of up to 80 percent. Ineffective in some sands	Rapid, simple, good underwater, soft under layers may damp vibrations, difficult to penetrate, stiff over layers, not good in partly saturated soils	Moderate
	Vibro-compaction	Densification by vibration and compaction of backfill material	Cohesionless soils with less than 20 percent fines	30 m	Granular backfill, water supply	Vibroflot, crane, pumps	Can obtain high relative densities; good uniformity	Useful in saturated and partly saturated soils	Moderate

	Summary of Ground Improvement Methods								
	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
<i>In-Situ Deep Compaction of Cohesionless Soils</i>	Compaction piles	Densification by displacement of pile volume and by vibration during driving	Loose sandy soils: partly saturated clayey soils, loess	> 20 m	Pile material (often sand or soil plus cement mixture)	Pile driver, special sand pile equipment	Can obtain high densities; good uniformity	Useful in soils with fines; uniform compaction; easy to check results; slow; limited improvement in upper 1-2 m	Moderate to high
	Heavy tamping (dynamic compaction/ consolidation)	Repeated application of high intensity impacts at surface	Cohesionless soils, waste fills, partly saturated soils	30 m	None	Tampers of up to 200 tonne, high capacity crane	Can obtain good improvement and reasonable uniformity	Simple, rapid, suitable for some soils with fines; usable above and below water, requires control, shall be away from existing structures	Low
<i>Injection and Grouting</i>	Particulate grouting	Penetration grouting fills soil pores with soil, cement, and/or clay	Medium to coarse sand and gravel	Unlimited	Grout, water	Mixers, tanks, pumps, hoses	Impervious, high strength with cement grout, eliminate liquefaction danger owing to filling of voids with grout	Low cost grouts, high strength; limited to coarse-grained soils, hard to evaluate	Lowest of the grout systems
	Chemical grouting	Solutions of two or more chemicals react in soil pores to form a gel or a solid precipitate	Medium silts and coarser	Unlimited	Grout, water	Mixers, tanks, pumps, hoses	Impervious, high strength void filled with cement grout, eliminate liquefaction danger	Low viscosity controllable gel time, good water shut-off; high cost, hard to evaluate	High to very high

	Summary of Ground Improvement Methods								
	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
<i>Injection and Grouting</i>	Pressure injected lime	Lime slurry injected to shallow depths under high pressure	Expansive clays	Unlimited, but 2-3 m usual	Lime, water surfactant	Slurry tanks, agitators, pumps, hoses	Lime in capsulated zones formed by channels resulting from cracks, root holes, hydraulic fracture	Only effective in narrow range of soil conditions	Competitive with other solutions to expansive soil problems
	Displacements grout	Highly viscous grout acts as radical hydraulic jack when pumped in under high pressure	Soft, fine-grained soils; foundation soils with large voids or cavities	Unlimited, but a few metre usual	Soil, cement water	Batching equipment, high pressure pumps, hoses	Grout bulbs within compressed soil matrix	Good for reduction of differential settlements; filling large voids; careful control required	Low (material) high (injection process)
	Electro-kinetic injection	Stabilizing chemicals moved into soil by electro-osmosis or colloids into pores by electrophoresis	Saturated silts; silty clays (clean sands in case of colloid injection)	Unknown	Chemicals stabilizer colloidal void fillers	d.c. power supply, anodes, cathodes	Increased strength, reduced compressibility, reduced liquefaction potential	Existing soil and structures not subjected to high pressures; not good in soils with high conductivity	Expensive
	Jet grouting	High speed jets at depth excavate, inject, and mix stabilizer with soil to form columns or panels	Sands, silts, clays	–	Water, stabilizing chemicals	Special jet nozzle, pumps, pipes and hoses	Solidified columns and walls	Useful in soils that can't be permeation grouted, precision in locating treated zones	High

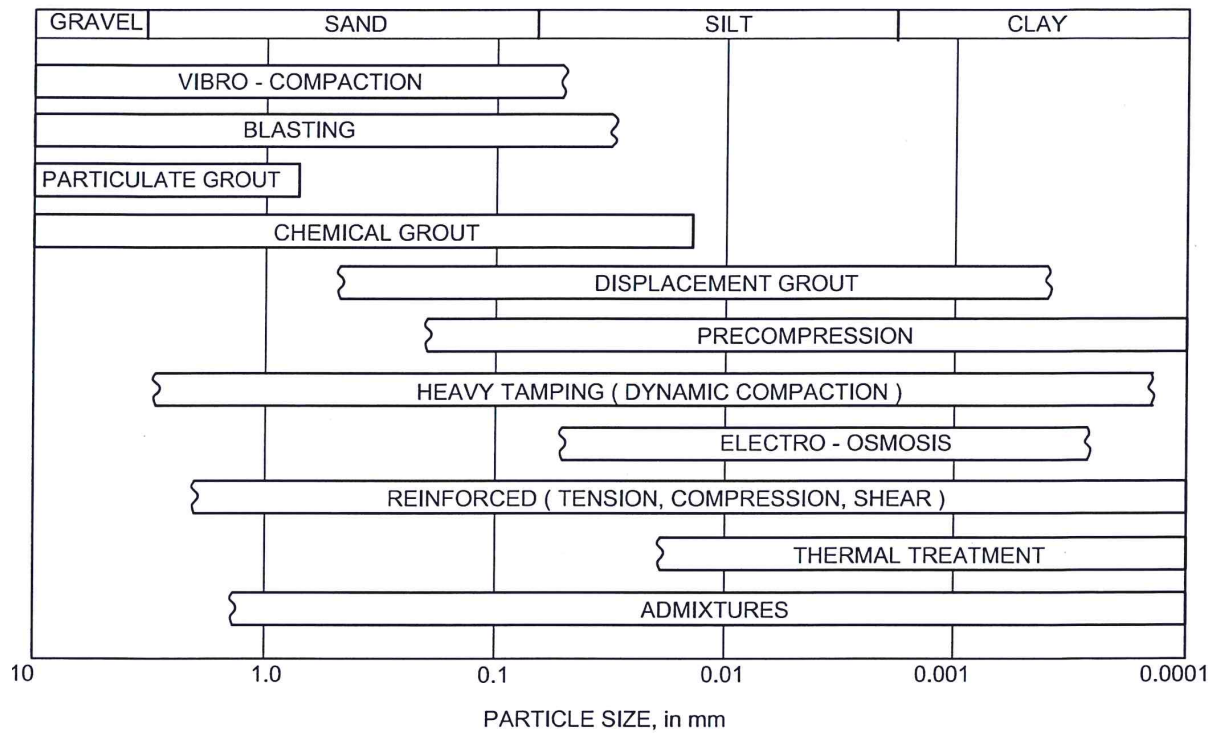
	Summary of Ground Improvement Methods								
	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
<i>Precompression</i>	Preloading with/without drains	Load is applied sufficiently in advance of construction so that compression/consolidation of soft soils is completed prior to development of the site	Normally consolidated soft clays, silts, organic deposits, completed sanitary landfills	–	Earth fill or other material for loading the site; sand or gravel for drainage blanket	Earth moving equipment, large water tanks or vacuum drainage systems sometimes used; settlement markers, piezometers	Reduced water content and void ratio, increased strength	Easy, theory well developed, uniformity; requires long time (vertical drains can be used to reduce consolidation time)	Low (moderate, if vertical drains are required)
	Surcharge fills	Fill in excess of that required permanently is applied to achieve a given amount of settlement in a shorter time; excess fill then removed	Normally consolidated soft clays, silts, organic deposits, completed sanitary landfills	–	Earth fill or other material for loading the site; sand or gravel for drainage blanket	Earth moving equipment; settlement markers, piezometers	Reduced water content, void ratio and compressibility increased strength	Faster than preloading without surcharge, theory well developed, extra material handling; can use vertical drains to reduce consolidation time	Moderate
	Electro-osmosis	d.c. current causes water flow from anode towards cathode where it is removed	Normally consolidated silts and silty clays	–	Anodes (usually rebars or aluminium) cathodes (well points or rebars)	d.c. power supply, wiring, metering systems	Reduced water content and compressibility, increased strength, electrochemical hardening	No fill loading required, can be used in confined area, relatively fast; non-uniform properties between electrodes; not good in highly conductive soils	High

	Summary of Ground Improvement Methods								
	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
<i>Admixtures</i>	Remove and replace	Foundation soil excavated, improved by drying or admixture addition, and re-compacted	Inorganic soils	10 m	Admixture stabilizers	Excavating, mixing and compaction equipment, dewatering system	Increased strength and stiffness, reduced compressibility	Uniform, controlled foundation soil when replaced; may require large area dewatering	High
	Structural fills	Structural fill distributes loads to underlying soft soils	Used over soft clays or organic soils, marsh deposits	–	Sand, gravel fly ash, bottom ash, slag, expanded aggregate, clam shell or oyster shell, incinerator ash	Mixing and compaction equipment	Soft subgrade protected by structural load-bearing fill	High strength, good load distribution to underlying soft soils	Low to high
	Mix-in-place piles and walls	Lime, cement, or asphalt introduced through rotating auger or special in-place mixer	All soft or loose inorganic soils	> 20 m	Cement, lime, asphalt, or chemical stabilizer	Drill rig, rotary cutting and mixing head, additive proportioning equipment	Solidified soil piles for walls of relatively high strength	Use native soil, reduced lateral support requirements during excavation; difficult quality control	Moderate to high

	Summary of Ground Improvement Methods								
	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
<i>Thermal</i>	Heating	Drying at low temperatures; alteration of clays at intermediate temperatures (400-600 °C); fusion at high temperatures (> 1 000 °C)	Fine-grained soils, especially partly saturated clays and silts, loess	15 m	Fuel	Fuel tanks, burners, blowers	Reduced water content, plasticity, water sensitivity; increased strength	Can obtain irreversible improvements in properties; can introduce stabilizers with hot gases	High
	Freezing	Freeze soft, wet ground to increase its strength stiffness	All soils	Several metres	Refrigerant	Refrigeration system	Increased strength and stiffness, reduced permeability	Not good in flowing ground water; temporary method	High
<i>Reinforcement</i>	Vibro replacement sand/stone columns	Hole jetted into soft, fine-grained soil and backfilled with densely compacted gravel or sand	Soft clays and alluvial deposits	20 m	Gravel or crushed rock backfill	Vibroflot, crane or vibrocat, water	Increased bearing capacity, reduced settlement	Faster than precompression, avoids dewatering required for remove and replace method; limited bearing capacity	Moderate to high
	Root piles, soil nailing	Inclusions used to carry tension, shear, compression	All soils	–	Reinforcing bars, cement grout	Drilling and grouting equipment	Reinforced zone behaves as a coherent mass	<i>In-situ</i> reinforcement for soils that cannot be grouted or mixed in-place with admixtures	Moderate to high
	Strips and membranes	Horizontal tensile strips, membranes buried in soil under embankments, gravel base courses and footings	All soils	Can construct earth structures to heights of several metres	Metal or plastic strips, geotextiles	Excavating, earth handling, and compaction equipment	Self-supporting earth structures, increased bearing capacity, reduced deformations	Economical, earth structures coherent, can tolerate deformations; increased allowable bearing pressure	Low to moderate

ANNEX B

(Clause 6.1.6.2)

GRAIN SIZE RANGES FOR DIFFERENT TREATMENT METHODS**B-1** Applicable grain size ranges for different treatment methods are given below:

NOTE — Jagged lines indicate uncertainty of applicability of the method.

ANNEX C

(Foreword)

COMMITTEE COMPOSITION

Soil and Foundation Engineering Sectional Committee, CED 43

<i>Organization</i>	<i>Representative(s)</i>
In Personal Capacity (Flat No. 202/395, Jodhpur Park, Kolkata 700068)	DR N. SOM (Chairman)
In Personal Capacity (D-1903, PWS, 7 Hills, Narsingi(v), Kokapet Road, Ranga Reddy 500089)	DR D. N. NARESH (Vice Chairman)
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Association of Consulting Civil Engineers (India), Bengaluru	SHRI SUDHANWA AMOL SHINGAREY SHRI CHANDRAMOULEESWAR S. (<i>Alternate</i>)
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Cengrs Geotechnica Pvt Ltd, Noida	SHRI SANJAY GUPTA SHRI RAVI SUNDARAM (<i>Alternate I</i>) SHRI SORABH GUPTA (<i>Alternate II</i>)
Central Board of Irrigation and Power, New Delhi	DIRECTOR
Central Designs Organization, Water Resources Deptt, Govt of Maharashtra, Nashik	SUPERINTENDING ENGINEER EXECUTIVE ENGINEER (<i>Alternate</i>)
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Consulting Engineering Services (India) Pvt Ltd, New Delhi	SHRI DIPANKAR PAUL SHRI T. K. ROY CHOUDHURY (<i>Alternate</i>)
CSIR-Central Building Research Institute, Roorkee	SHRI MANOJIT SAMANTA DR S. GANESH KUMAR (<i>Alternate</i>)
CSIR-Central Road Research Institute, New Delhi	SHRI KANWAR SINGH DR P. S. PRASAD (<i>Alternate</i>)
CSIR-Structural Engineering Research Centre, Chennai	DR P. KAMATCHI SHRIMATI R. SREEKALA (<i>Alternate</i>)
D-CAD Technologies, New Delhi	DR K. G. BHATIA
Delhi Development Authority, New Delhi	SHRI GOVIND RAM SHIROMANI SHRI K. K. GUPTA (<i>Alternate</i>)
Delhi Technological University, Delhi	PROF ASHOK KUMAR GUPTA

<i>Organization</i>	<i>Representative(s)</i>
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Gammon Engineers and Contractors Pvt Ltd, Mumbai	SHRI VENKATARAMANA. N. HEGGADE SHRI SANDEEP M. GHAN (<i>Alternate</i>)
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Geological Survey of India, Kolkata	DR TIMIR BARAN GHOSAL SHRI PRASHANT TUKARAM ILAMKAR (<i>Alternate</i>)
Ground Engineering Limited, New Delhi	SHRI ASHOK KUMAR JAIN SHRI NEERAJ KUMAR JAIN (<i>Alternate</i>)
Gujarat Engineering Research Institute, Vadodara	SHRI K. A. KESHVANI SHRI R. S. VASAVA (<i>Alternate</i>)
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Indian Institute of Technology Madras, Chennai	PROF SUBHADEEP BANERJEE PROF RAMESH K. KANDASAMI (<i>Alternate</i>)
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Indian Institute of Technology Roorkee, Roorkee	PROF MAHENDRA SINGH PROF VISHWAS A. SAWANT (<i>Alternate</i>)
Indian Road Congress, New Delhi	SECRETARY GENERAL DIRECTOR (T) (<i>Alternate</i>)
Indian Society of Earthquake Technology, Roorkee	PROF T. G. SITHARAM DR B. K. MAHESWARI (<i>Alternate</i>)
ITD Cementation India Ltd, Kolkata	SHRI MANISH KUMAR SHRI SACHIN KAMAT (<i>Alternate</i>)
Jadhavpur University, Kolkata	PROF SIBAPRIYA MUKHERJEE PROF RAMENDU BIKAS SAHU (<i>Alternate</i>)
Keller Ground Engineering Pvt Ltd, Chennai	SHRI V. V. S. RAMADAS SHRI MADAN KUMAR ANNAM (<i>Alternate</i>)
Larsen and Toubro Limited, Chennai	DR K. S. RAMAKRISHNA SHRI JESUDOSS ASIRVATHAM (<i>Alternate</i>)
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M N Dastur & Company (P) Limited, Kolkata	DR ABHIJIT DASGUPTA SHRI SUVENDU DEY (<i>Alternate</i>)
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